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Fatigue Study of the Linthkanal-Brücke

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Motivation and objectives

As fatigue cracks were discovered under the bridge deck of the 48 years old railway bridge Linthkanal-Brücke, located near the Ziegelbrücke town in Switzerland, a few studies were conducted to understand the mechanism behind the cracks formation. However, the results of them were not conclusive. The purpose of this study is to elaborate a deeper understanding of this steel tied-arch bridge behaviour in order to find out the effects causing fatigue cracks to develop at specific locations: in the lower weld junctions and the mouse holes of the transversal stiffeners.

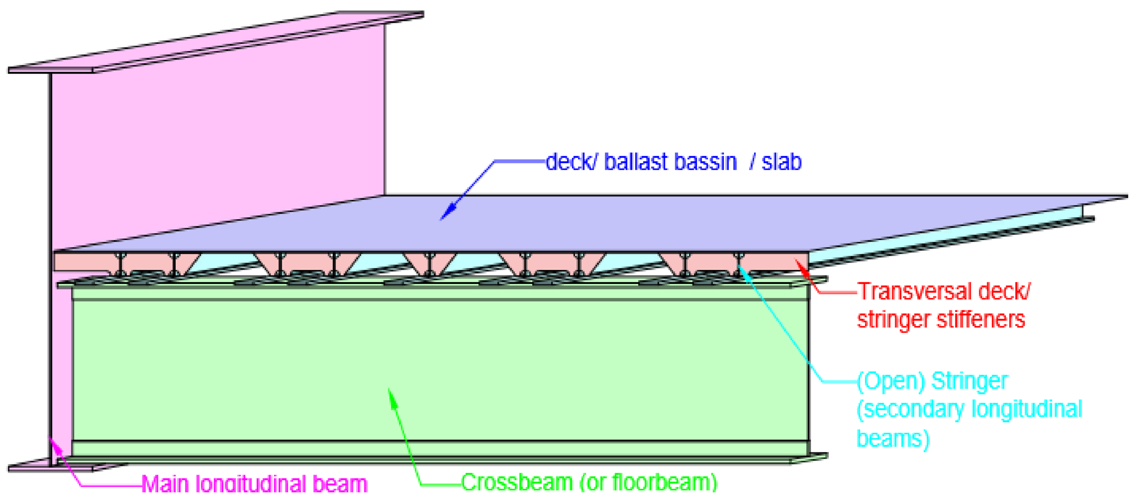


Figure 1: Schematic drawing of the bridge deck elements

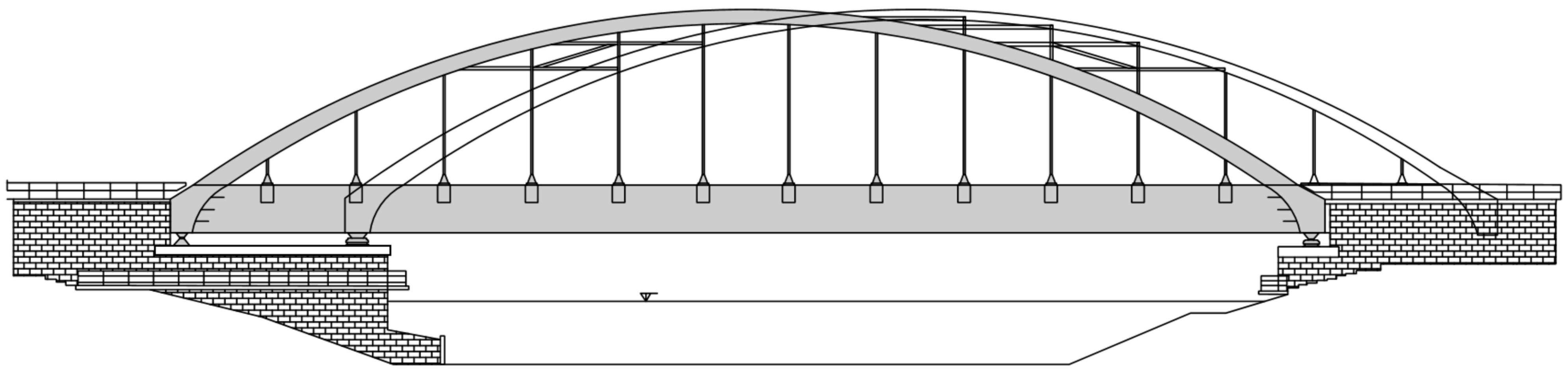


Figure 2: Drawing of the bridge, side view

Means of Action

To achieve this goal, a complete finite element modelling of the structure was conducted with SCIA software, using a refined plate sub-model inserted in a global bar model, to mimic the structural behaviour of the bridge deck. A distributed train carriage load was set in motion over the bridge deck, and the stresses found under each loads position were used to carry out a fatigue analysis in various elements including the critical details where damages were encountered.

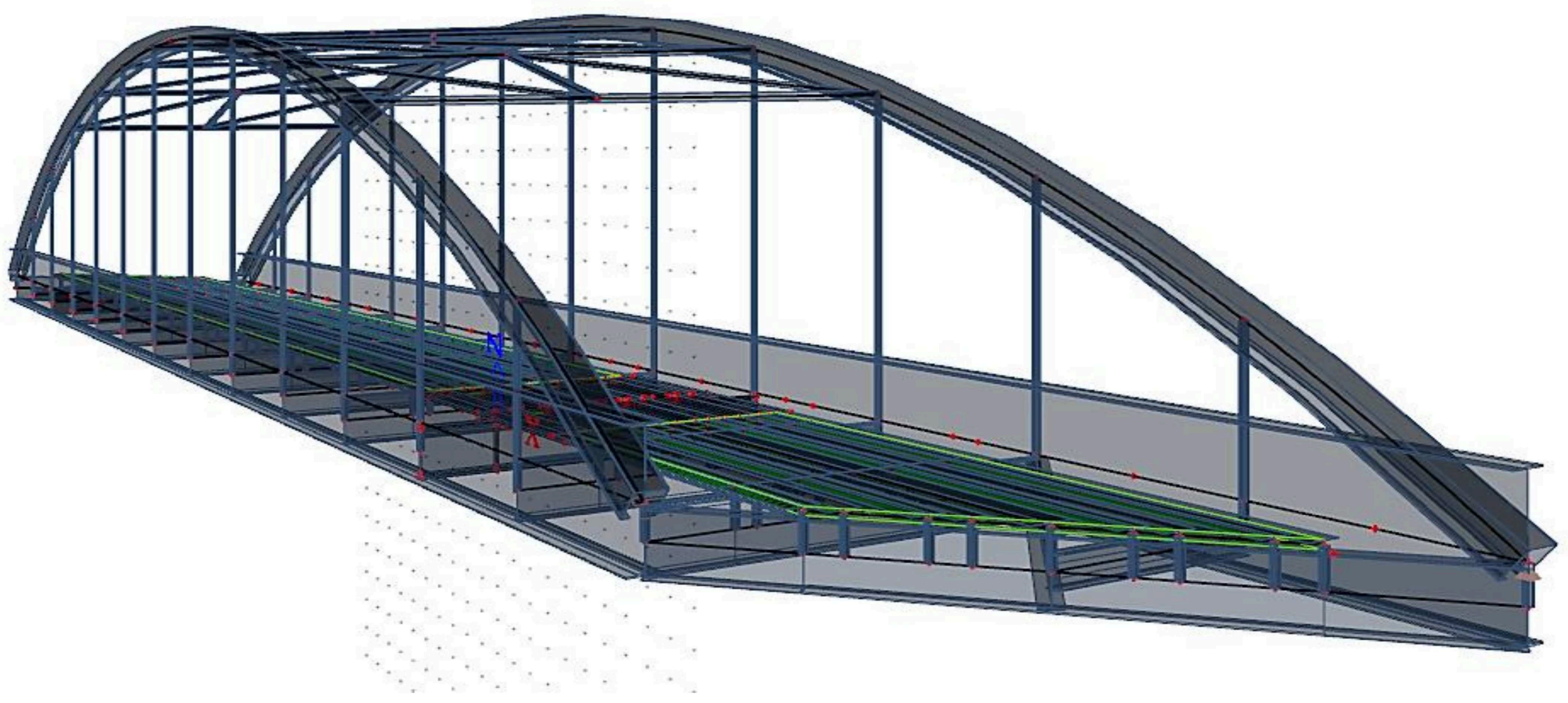


Figure 3: 3D final model on SCIA, side view

Fatigue life check in the hangers

As the locations of the cracks were of very complex geometry, the fatigue assessment methods had to be adapted to the detail geometry and the level of modelling enabled by the software chosen to perform the study. As an additional check, the nominal stress method was used to assess the bridge hangers fatigue life.

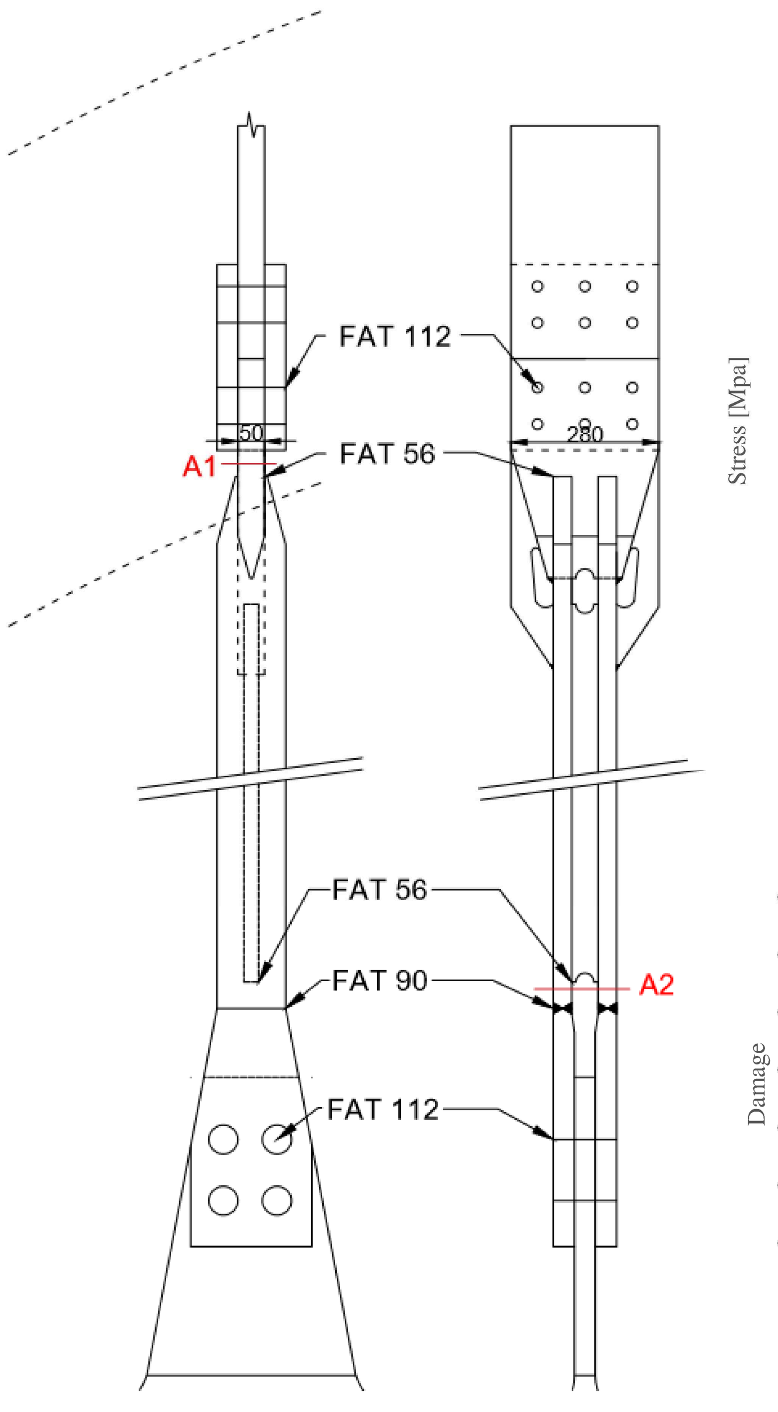
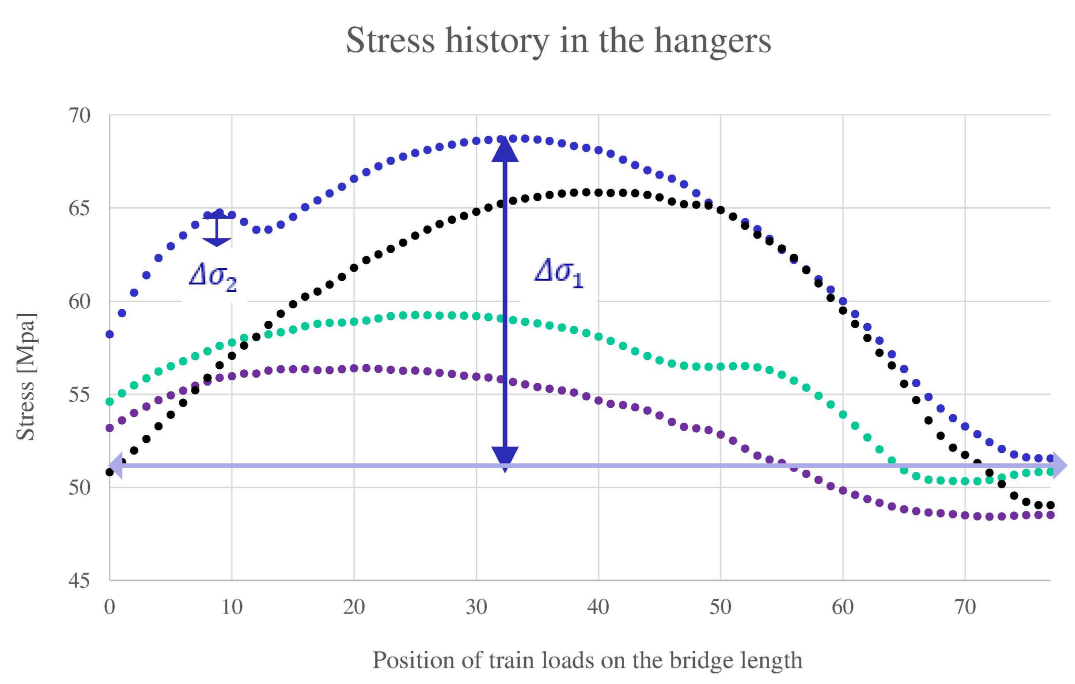
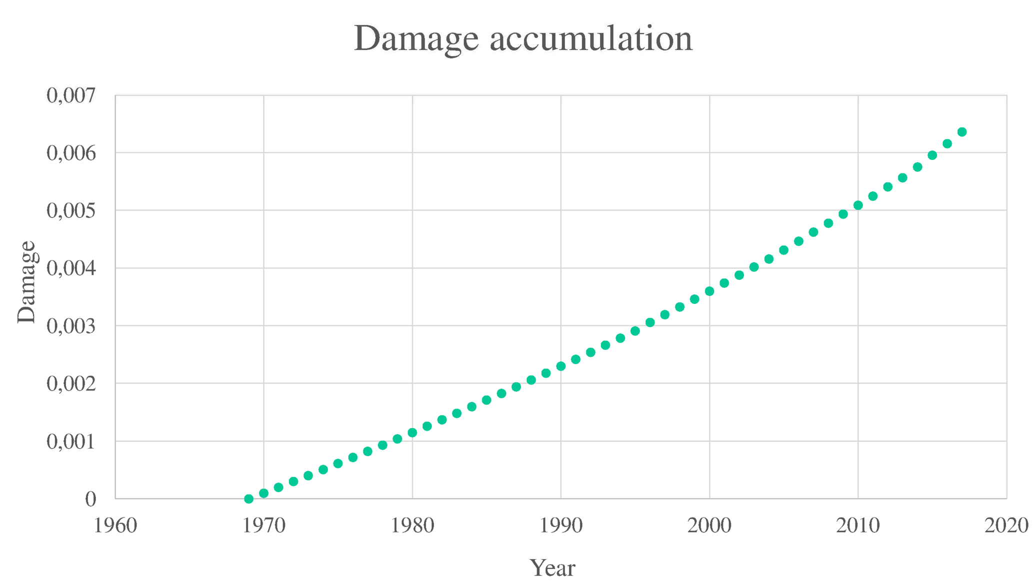


Figure 4: Fatigue classification of the details at risks in the hangers





Fatigue analysis methods

Since a detailed sub-model in plate elements was built, a sensible choice of fatigue control was the structural hot-spot method to evaluate the stress range in the weld details at risk. This approach provides a linearized value of the stress peak in the weld toe, thus allowing a more precise analysis of the problematic area. An altered structural hot-spot method was applied to another set of details comparable to a mouse hole.

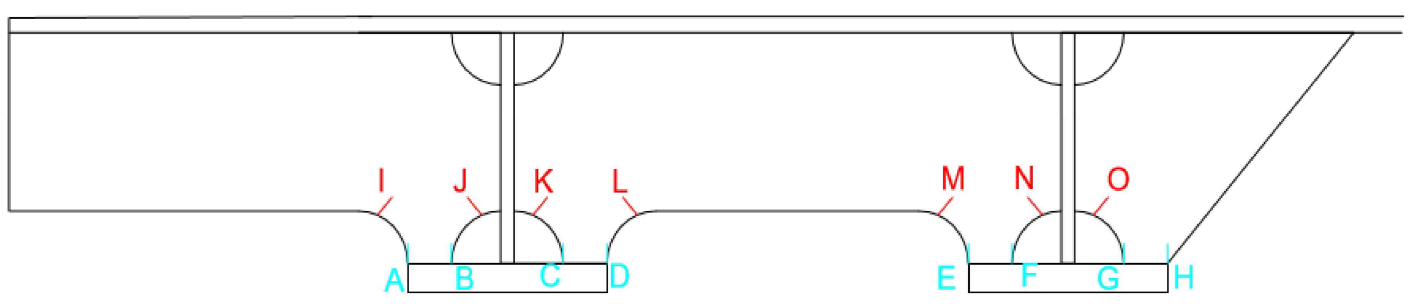


Figure 5: Drawing of the details of the transversal stiffeners checked under fatigue

Results

The damages occurring under the passing of one train were calculated using the hot-spot method, and every details at risk were compared. Ultimately, the lower welds of the transversal stiffeners were discovered to be the most likely to fail under fatigue.

Area	Points	Di
Welds	A	4,11801E-05
	B	2,78936E-06
	C	8,54487E-05
	D	1,61623E-05
	E	1,89111E-05
	F	3,94983E-05
	G	1,85714E-06
	H	0
Curves	I	0
	J	2,08401E-06
	K	3,64965E-07
	L	8,7368E-06
	M	3,04993E-06
	N	3,1855E-07
	O	4,14785E-07

Table 1: Comparative table of the damages in the studied detail under the passing of 1 train

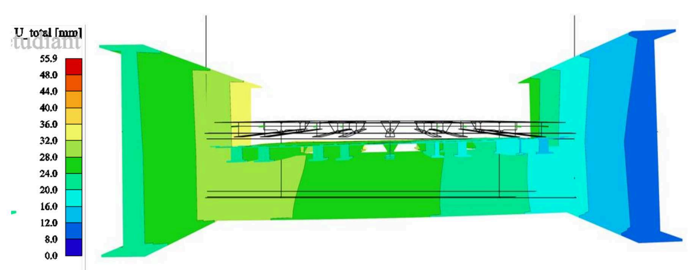


Figure 6: Displacements of the deck under the passing of a train carriage

Figure 7: Damages pictures

Conclusion

The results showed that, while the hangers of the bridge are not at risk of fatigue failure, the cracks in the critical details of the transversal stiffeners on top of the crossbeams are explainable. Indeed, the very rigid connection between the crossbeam and the bridge main span deck creates a mixed system behaviour, very similar to an orthotropic deck. This outcome was supported by the existing crack locations found in the bridge. This understanding back-up the recommendation of loosening the bolts connecting the crossbeams and the deck stiffeners elements. Hence this action would result in reducing the connection between the aforementioned elements and relieve the details under strong fatigue loads.

Eventually, this study could also be applicable to bridges built in Switzerland with similar “orthotropic decking”, in addition to helping the increase of the Linthkanal-Brücke bridge service life duration.